1 OF 1

AD476 132

RESEARCH NOTE 20

ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES

by A. L. Morsell

HELIODYNE CORPORATION
Los Angeles, California 90064

June, 1965

supported by

ADVANCED RESEARCH PROJECTS AGENCY

under ARPA Order 360
monitored by the
U.S. ARMY MISSILE COMMAND
Redstone Arsenal
Huntsville, Alabama

under Contract No. DA 04-495-AMC-458(Z)

This research is a part of Project DEFENDER, sponsored by the Advanced Research Projects Agency, Department of Defense.

RN20, 6-65

ACKNOWLEDGMENT

The author wishes to thank Dr. W. J. Hooker for many enlightening discussions. The author is indebted to R. H. Ueunten, R. P. Sellers, Jr., and R. R. Holden for their able assistance with the design and construction of the apparatus and with the operation of the shock tube.

ABSTRACT

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.

No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

TABLE OF CONTENTS

1. INTRODUCTION

A method has been developed at Heliodyne Corporation for suspending finely-divided powder in the test gas of a shock tube in order to investigate the properties of reentry vehicle materials under conditions simulating those of actual flight. One of the properties of interest is the electron density in the mixture of hot air and ablated material. However, since the conductivity of the test gas is directly proportional to electron density and dependent on other variables, such as collision frequency, which vary much less rapidly than electron density, then a measurement of conductivity is a satisfactory substitute for a direct measurement of electron density. The method chosen for measuring conductivity is simple, covers a wide range of conductivities, and is much less expensive than the microwave equipment needed to make a direct measurement of electron density.

The method described here is similar to the magnetic induction method reported by Lin, Resler, and Kantrowitz[1]. Through the use of a somewhat more complicated field coil configuration we have been able to improve upon the spatial resolution reported by Lin, and the addition of an integrating circuit permits the direct observation of the conductivity profile of the shock-heated gas.

The initial shock tube pressure at which the data are taken is dictated by the fact that in order to obtain a uniform distribution of powder in the test gas without at the same time producing too great a powder-to-air mass ratio it has been found necessary to use initial shock tube pressures of at least 1 cm Hg. This pressure is higher than the initial pressures for which conductivity measurements have been reported in the literature. Lamb and Lin[2] have measured the conductivity of air for shock speeds ranging from 3.4 to 6.0 mm/μsec for an initial shock tube pressure of 1 mm Hg.

In a later article Lin, Neal, and Fyfe[3] report on ionization rate measurements in air at very low initial pressures (0.02 to 0.2 mmHg.) using a large-diameter, low-density shock tube with a small magnetic-induction probe mounted inside the tube.

2. BRIEF ANALYSIS OF THE EXPERIMENT

Since a thorough mathematical analysis of the magnetic induction probe is given in Reference 1, only a brief analysis is needed here.

One assumes that a column of plasma with slowly varying conductivity is passing across a boundary separating a uniform axial magnetic field of one value from a uniform axial magnetic field of another value. In the region of the discontinuity the field is strongly radial, and in this region the interaction of the moving plasma with the radial field generates currents in the plasma circulating around the axis. These circulating currents produce magnetic lines of force which thread a sensing coil wound around the shock tube at the region of strong radial field. It can be easily shown that the flux threading the sensing coil may be written as follows:

$$\Phi = \frac{-k}{12}\pi a^3 \mu_o \sigma U \Delta B_Z, \tag{1}$$

where $k \leq 1$ is a constant depending on the geometry, a is the shock tube radius, μ_o is the permeability of free space, σ is the conductivity of the plasma, U is the velocity of the plasma, and ΔB_Z is th change in axial magnetic field strength across the region of discontinuity. For a sensing coil with N turns the induced voltage is

$$\epsilon = -N \frac{d\Phi}{dt}. \tag{2}$$

Thus,

$$\int_{t_o}^{t} \epsilon \, dt = -N\Phi \tag{3}$$

if t_o represents a time before the conducting slug of plasma has reached the field discontinuity, so that $\Phi(t_o) = 0$. Substituting Eq.(1) into Eq. (3) and rearranging terms gives the following result:

$$\sigma(t) = \frac{12 \int \epsilon \, dt}{Nk\pi a^3 \mu_o U \Delta B_Z} = \frac{K \int \epsilon \, dt}{U \Delta B_Z} \qquad (4)$$

if the product of the constant factors is set equal to K.

In deriving Eq. (1) the following assumptions have been made: (1) the magnetic field due to induced currents is small compared to the change ΔB_Z in the steady field; (2) the inductive time constant of the plasma is short compared with the time resolution desired of the measurement; (3) coupling between the plasma current and the field coil assembly, which has a long inductive time constant, is not so severe as to seriously limit the time response of the apparatus; and (4) the conductivity of the plasma is not altered by the presence of the magnetic field.

It can be easily shown that assumption (1) is valid. The field strength due to the induced currents may be written

$$B \approx \frac{\Phi}{\pi a^2}, \qquad (5)$$

so that we find from Eq. (1) that

$$\frac{B}{\Delta B_Z} = \frac{-k}{12} a \mu_o \sigma U. \qquad (6)$$

For a = 0.0381 m and the extreme values k = 1, σ = 100 mhos/m, and U = 6×10^3 m/sec the ratio $B/\Delta B_Z = 2.4 \times 10^{-3}$.

The validity of assumption (2) is shown as follows: The inductance and the resistance of a conducting ring of plasma may be approximated by the expressions

$$L \approx \frac{\mu_o \pi r}{2} \tag{7}$$

and

$$R \approx \frac{2\pi r}{\sigma b w} \tag{8}$$

where r is the mean radius of the ring, b is the thickness of the ring, and w is the width of the ring. The time constant

$$\tau \approx \frac{L}{R} \approx \frac{\mu_o \sigma b w}{4} \tag{9}$$

For the extreme values σ = 100 mhos/m and b = w = 0.03m (the shock tube radius is 0.038 m) we find τ = 30 nsec, much too small to worry about.

The validity of the third assumption depends on the field coil geometry. For the geometry described in the next section the coupling between the field coil and the plasma current has been shown to have a negligible effect on the time response of the sensing coil. The effect of the slug of plasma was simulated by a magnetic pulse produced by passing current from a pulse generator through several turns of wire inside the shock tube.

The fourth assumption is valid only if the paths of electrons in the plasma are not curved appreciably by the magnetic field during the free time between collisions with other plasma particles.

This condition will hold only if the collision frequency in the plasma is much greater than the cyclotron frequency of the electrons. For our case the collision frequency is never less than 10^{11} /sec whereas the cyclotron frequency for a field of 140 gauss is 4×10^{8}/sec.

For the case of the work of Lamb and Lin[2], at a lower initial shock tube pressure and higher field strength, the collision frequency and the cyclotron frequency were approximately equal, and the conductivity being measured was not a strictly scalar quantity.

3. DESIGN OF THE EXPERIMENT

Figure 1 shows the relationship among the various pieces of experimental apparatus. To avoid overheating the coil assembly the field coil is energized 1/2 second before the shock tube is fired and remains energized for just a few seconds. The coil assembly is shown in cross section in Fig. 2. The current in the two pancake coils on the left-hand side flows counter to the current in the two right-hand coils, so that the field pattern is that shown in Fig. 3. Twelve volts across the coil produces a current of 78 amperes and a maximum field strength on each side of the plane of symmetry of about 140 gauss, for a total change in axial field strength ΔB_Z of 280 gauss. To avoid large microphonic effects from acoustic waves in the shock tube wall it has been found necessary not only to install a sliding joint in the shock tube but also to mechanically isolate the coil assembly from the shock tube wall, as shown in Fig. 2.

The sensing coil is wound in the manner suggested by Lin[1]: two wires are wound side by side to form two overlapping coils of 18 turns each, and the start of one coil is connected to the end of the other coil to form a grounded center tap of a coil of 36 turns. Number 34 wire was used; the coil is 1/8 inch wide and wound in two layers. As explained by Lin[1], the center-tapped arrangement is needed to avoid picking up an electrostatic signal resulting from the fact that the shock-heated gas carries a net electrostatic charge. The presence of charge near the coil has nearly equal effects on the two ends of the coil, and this common-mode signal is rejected by the difference amplifier.

The difference amplifier shown in Fig. 4 converts the double-ended signal from the coil to the single-ended signal required by the integrator shown in Fig. 5. Because the integrator behaves as a high-gain amplifier for low frequency signals, it was necessary to

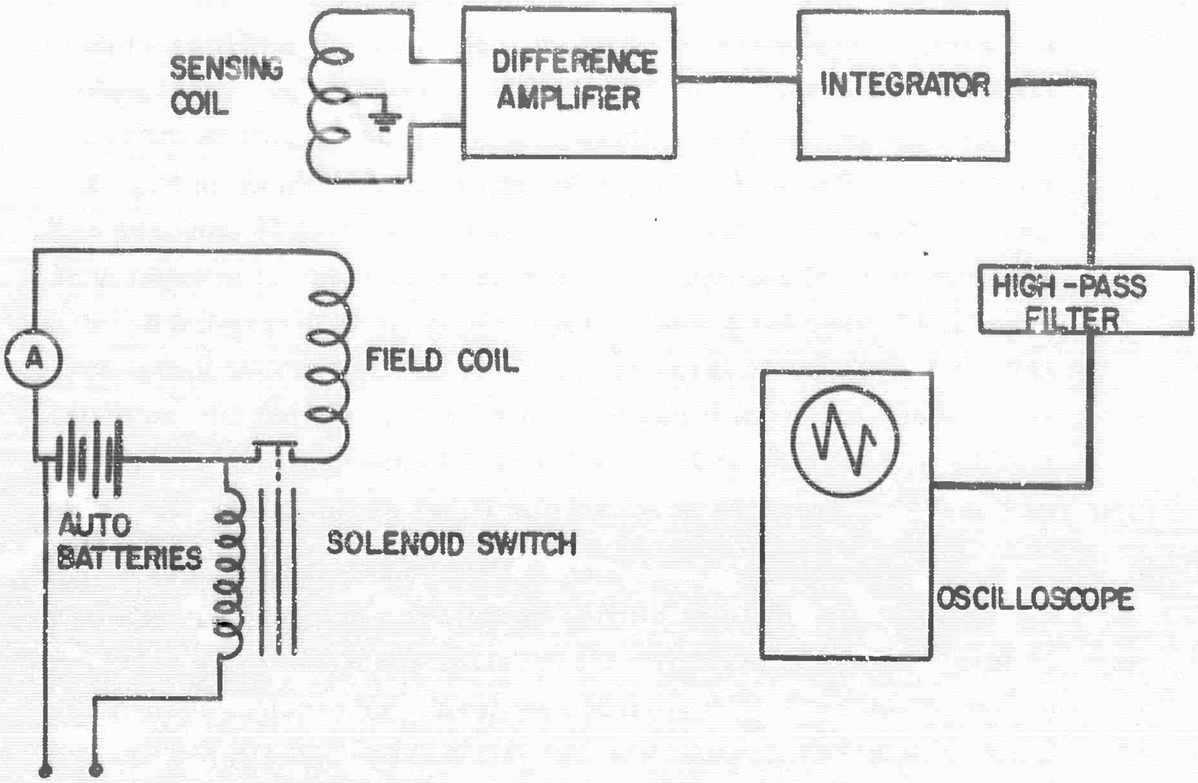

Fig. 1 Schematic circuit diagram.

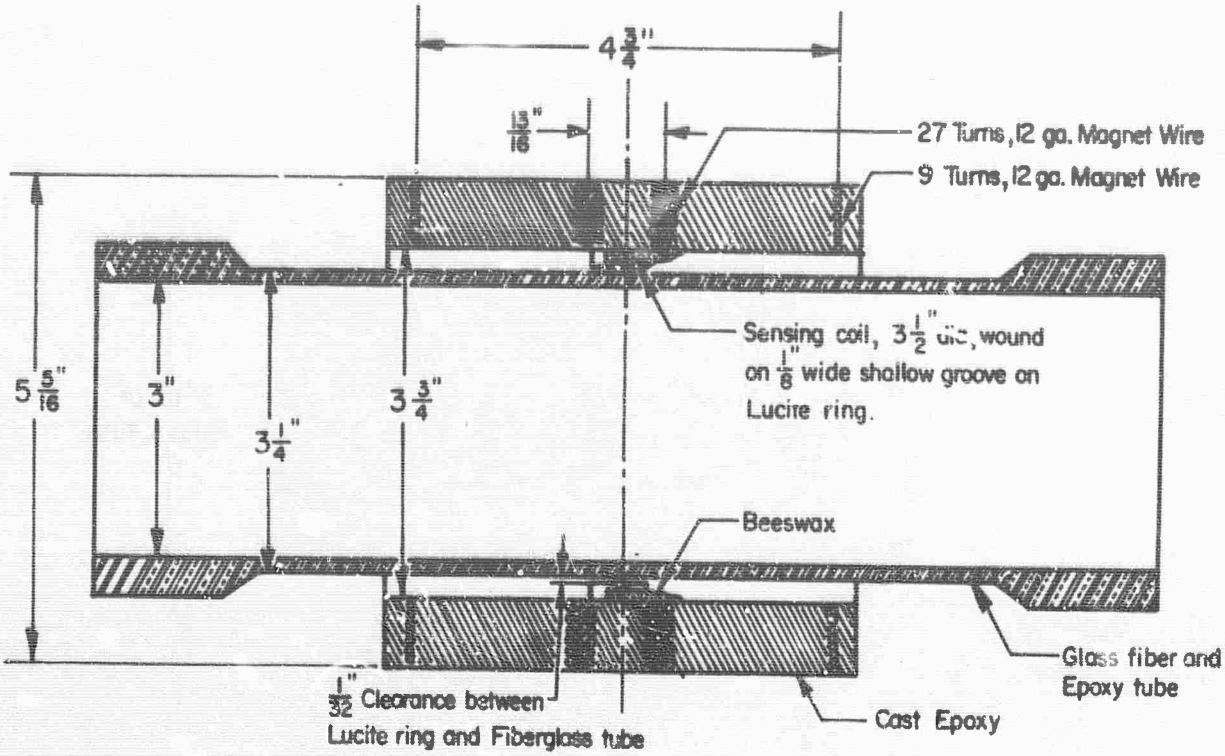

Fig. 2 Coil assembly and shock tube section.

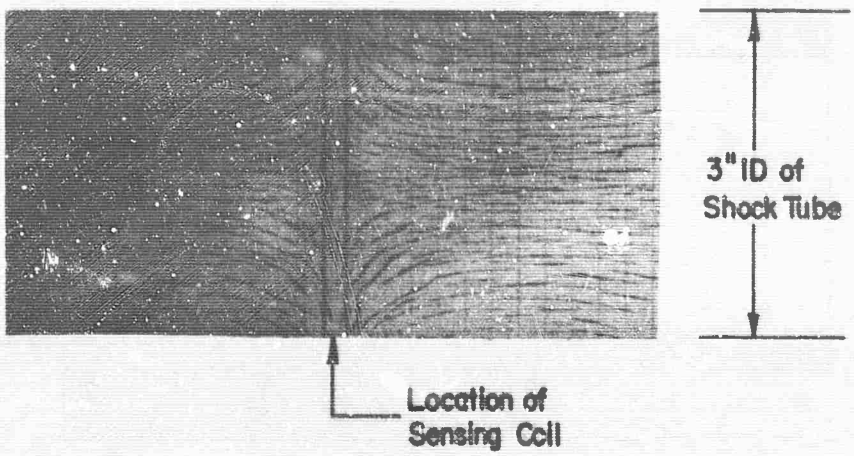

Fig. 3 Iron filing plot of the magnetic field pattern of the field coils.

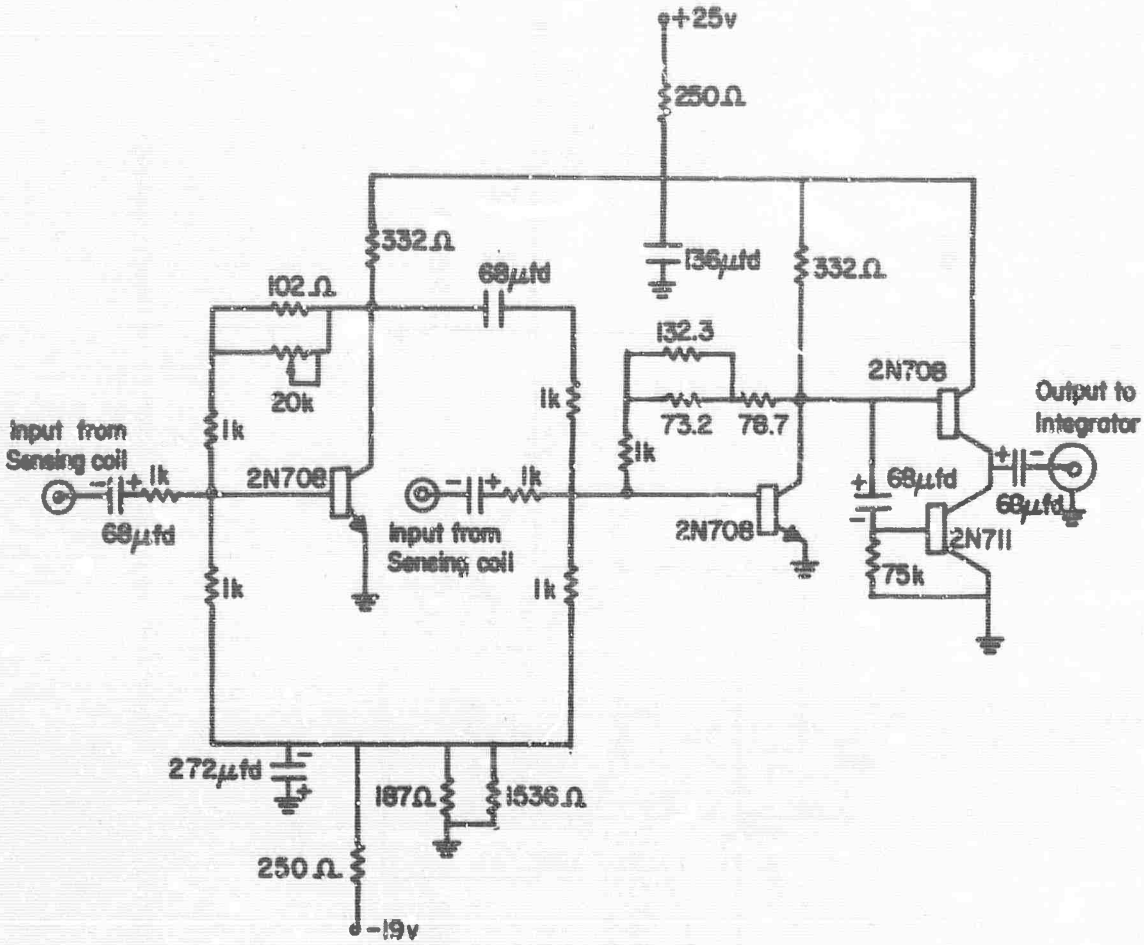

Fig. 4 Low input impedance difference amplifier with unity gain.

323

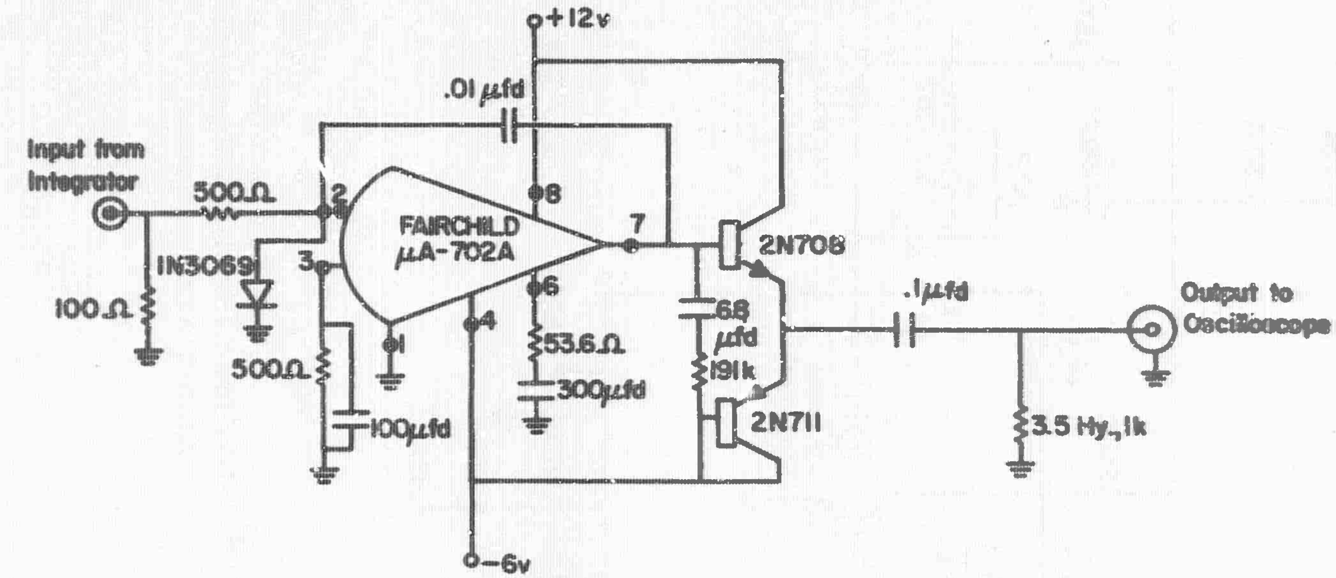

Fig. 5 Integrator circuit with filter for rejecting low-frequency noise.

minimize low-frequency noise in the difference amplifier, to carefully shield against 60 cps pickup, and to add a high-pass filter to the integrator after the complementary emitter-follower buffer stage.

3.1 CALIBRATION OF THE APPARATUS

In principle it is possible to calculate the constant K and the field ΔB_Z of Eq. (4) from the geometrical properties of the coil configuration. However, it is easier to propel a slug of material of known conductivity through the coil and compute the unknown constants from the observed voltage pulse at the coil terminals. The conductivity of a thin ring of aluminum was measured using a resis tance bridge, and a cylindrical slug 7 1/2 inches long by 2.960 inches in diameter was machined from the same material. When propelled through the shock tube at about 2.5 ft/sec the aluminum slug produced the signal shown in Fig. 6.

It is necessary to use this very slow speed to avoid distortion caused by the long inductive time constant of the aluminum slug. An approximate value for the time constant of the slug may be obtained from Eq. (9). For the measured conductivity of 1.79×10^7 mhos/m and the values $b = w = 0.03$m the time constant τ is about 5 ms, about equal to the value deduced from distortion of the calibration signal when high slug velocities were employed. To achieve uniform slow velocities for the slug it was necessary to pull the slug by a short, inelastic wire wound up on a motorized drum.

The signal of Fig. 6 is proportional to the time derivative of the conductivity of the material at the central plane of the coil assembly. Because the magnetic field is not abruptly discontinuous, but has radial components extending over an appreciable axial distance, the signal is spread somewhat. The signal spread corresponds to a resolution distance of 0.96 inches when computed from the half-height width of the peaks in Fig. 6.

The calibration constant is obtained from the following equation:

$$C = \frac{\int \epsilon \, dt}{\sigma I U} \tag{10}$$

where $\int \epsilon \, dt$ is the area under one of the calibration signal peaks, σ is the known conductivity of the aluminum slug, I is the field coil current, and U is the velocity of the slug, computed from a knowledge of the length of the slug and the time between the peaks of the calibration signal. For Fig. 6 $\int \epsilon \, dt = 1.465 \times 10^{-4}$ v sec, $\sigma = 1.79 \times 10^{7}$ mhos/m, I = 84.5 amperes, and U = 0.777 m/sec, resulting in a value for C of 1.25×10^{-13} ohm v sec^2/ampere.

The poor low-frequency response of the difference amplifier and the integrator prevented their use with the slow-moving aluminum slug. The difference amplifier has a voltage gain of 1 and thus has no influence on the calibration. The integrator constant κ is defined thus:

$$V = \kappa \int \epsilon \, dt, \tag{11}$$

where V is the integrator output voltage and ϵ is the input voltage. For the circuit of Fig. 5 it can be shown that $\kappa = 1/RC'$, where R is the 500 ohm input resistor and C' is the 0.01 μf feedback capacitor, so that $\kappa = 2 \times 10^{5}$/sec. This value checked well with the value obtained from a measurement of the amplitude of the triangular signal obtained by integrating a 1 kilocycle square wave.

If Eqs. (10) and (11) are combined, values for the constants are inserted, and the resulting equation is solved for σ, the result is

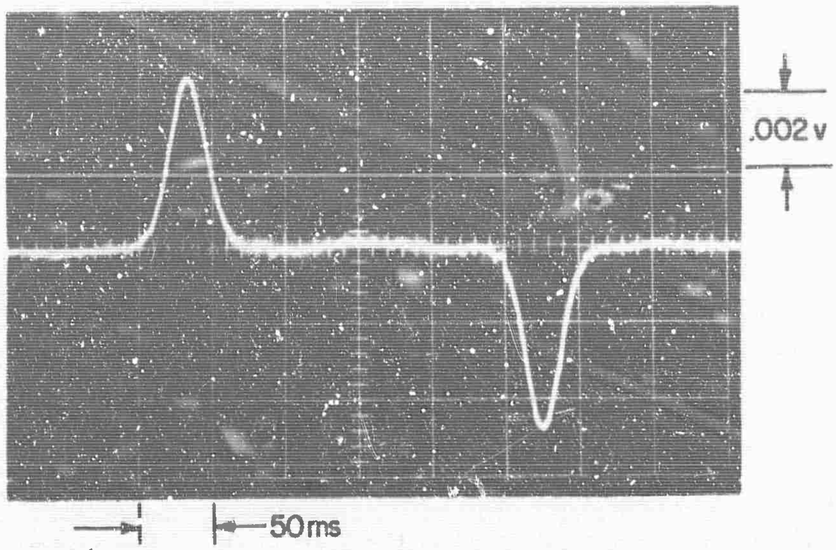

Fig. 6 Sensing coil signal produced by the motion of an aluminum slug through the coil assembly.

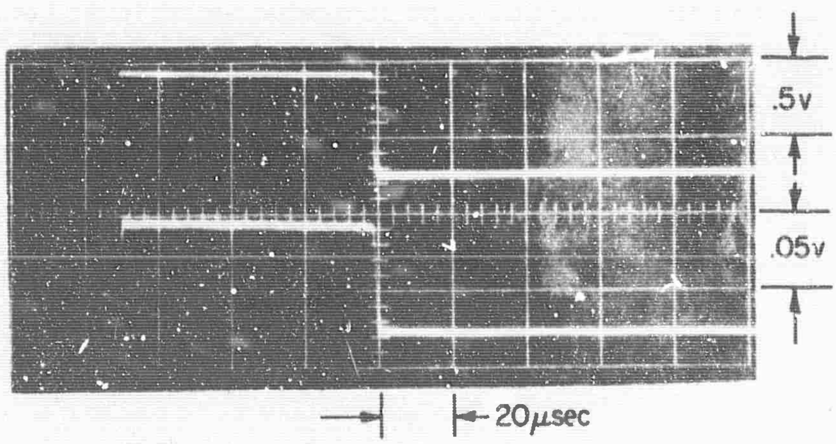

Fig. 7 Response of the sensing coil, difference amplifier, and integrator to a magnetic field pulse. Upper signal: current in 3-turn driving coil; lower signal: output of integrator.

$$\sigma = \frac{4.0 \times 10^7 V}{IU} \text{ mhos/m.} \tag{12}$$

The high-frequency response of the combination of the coil assembly with the field coil terminals shorted, the difference amplifier, and the integrator, with its noise filter, was checked by simulating the magnetic field pulse from the shock-heated plasma by a three-turn coil connected to a pulse generator. Fig. 7 shows that the rise time of the coils and the circuitry is of the order of 1μ sec or less and that there is very little distortion of the signal.

3.2 EXPERIMENTAL RESULTS

Figures 8 and 9 show some typical conductivity profiles obtained for shock-heated pure air (Fig. 8) and for a mixture of pure air and teflon powder (Fig. 9). Since the heights of the plateaus of the conductivity profiles were somewhat ambiguous, both the plateau maxima and minima were plotted in Fig. 10 against the shock speed U_s, determined from the raster record of heat transfer gauge signals at the upper left of each photograph.

The values for conductivity were obtained from the oscilloscope signals by use of Eq. 12. In this equation U is not the shock speed U_s but rather the speed of the gas behind the shock. The value of U is easily determined from U_s by the relationship

$$U = U_s \left(1 - \frac{\rho_1}{\rho}\right), \tag{13}$$

where ρ_1/ρ is the density ratio across the shock front. The value for ρ_1 is determined from the initial pressure in the shock tube, and the density behind the shock ρ is obtained from tables[4] of the normal shock properties of pure air. The fact that the properties

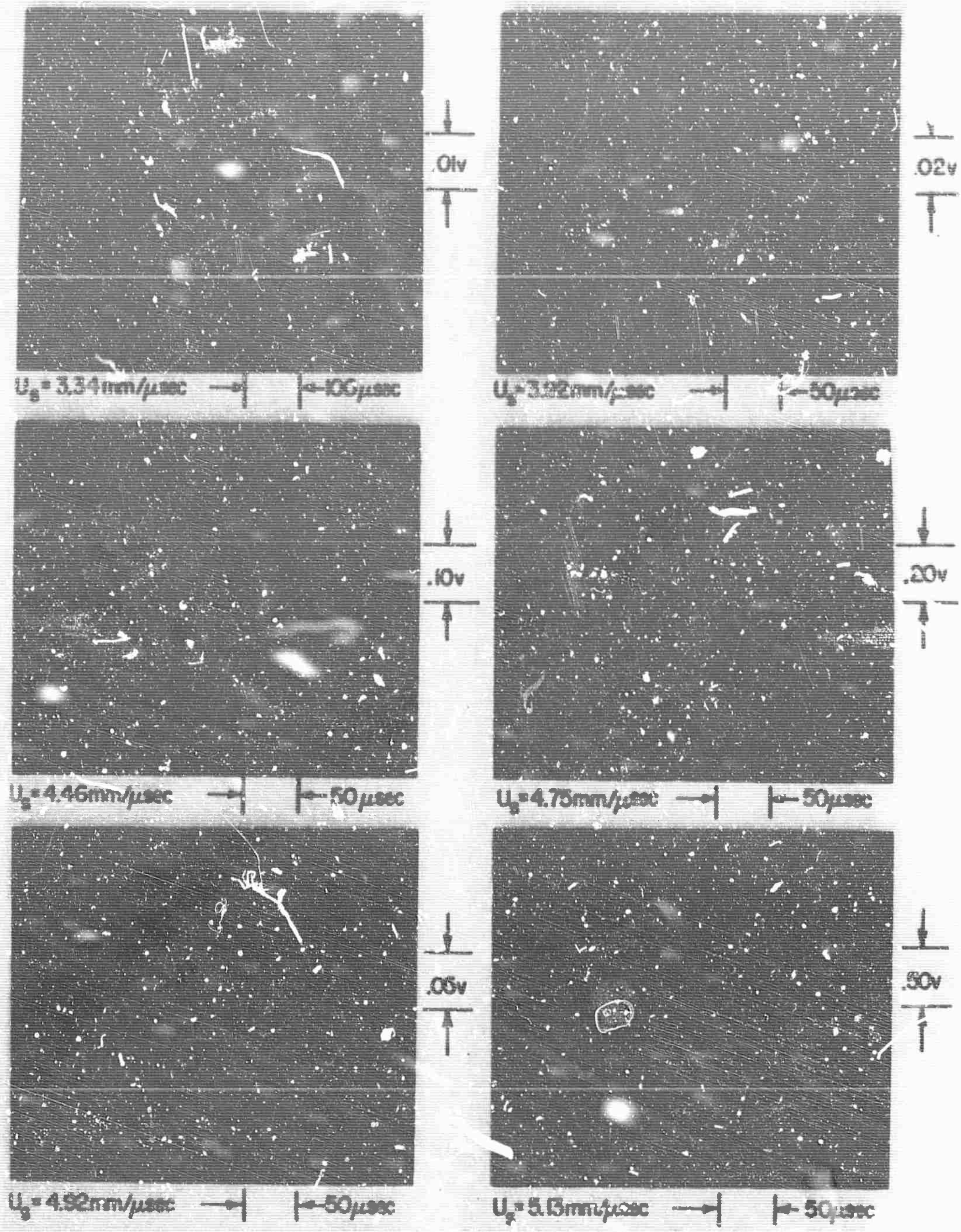

Fig. 8 Conductivity oscillograms for pure air for various shock speeds.

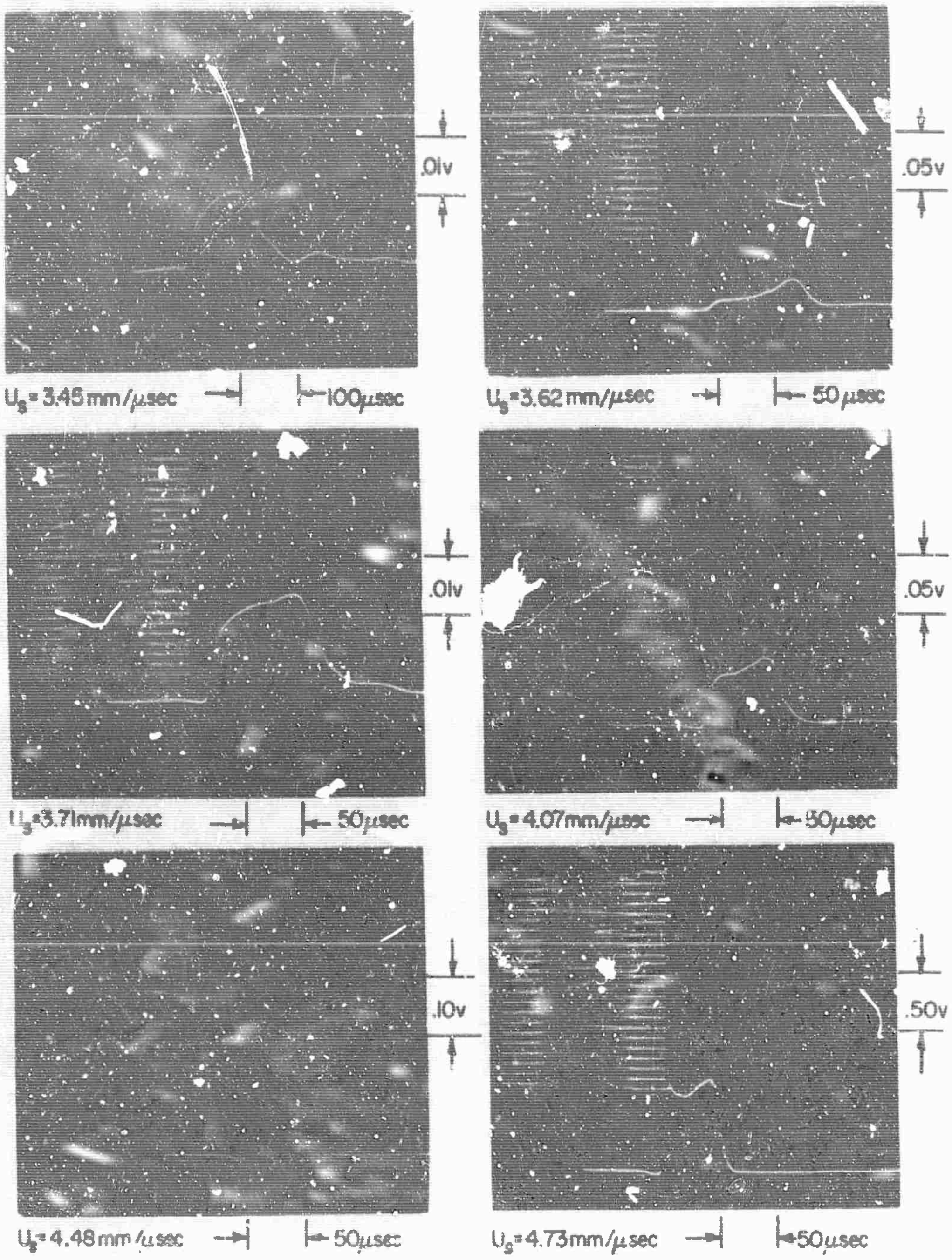

Fig. 9 Conductivity oscillograms for air-plus-teflon mixtures for various shock speeds.

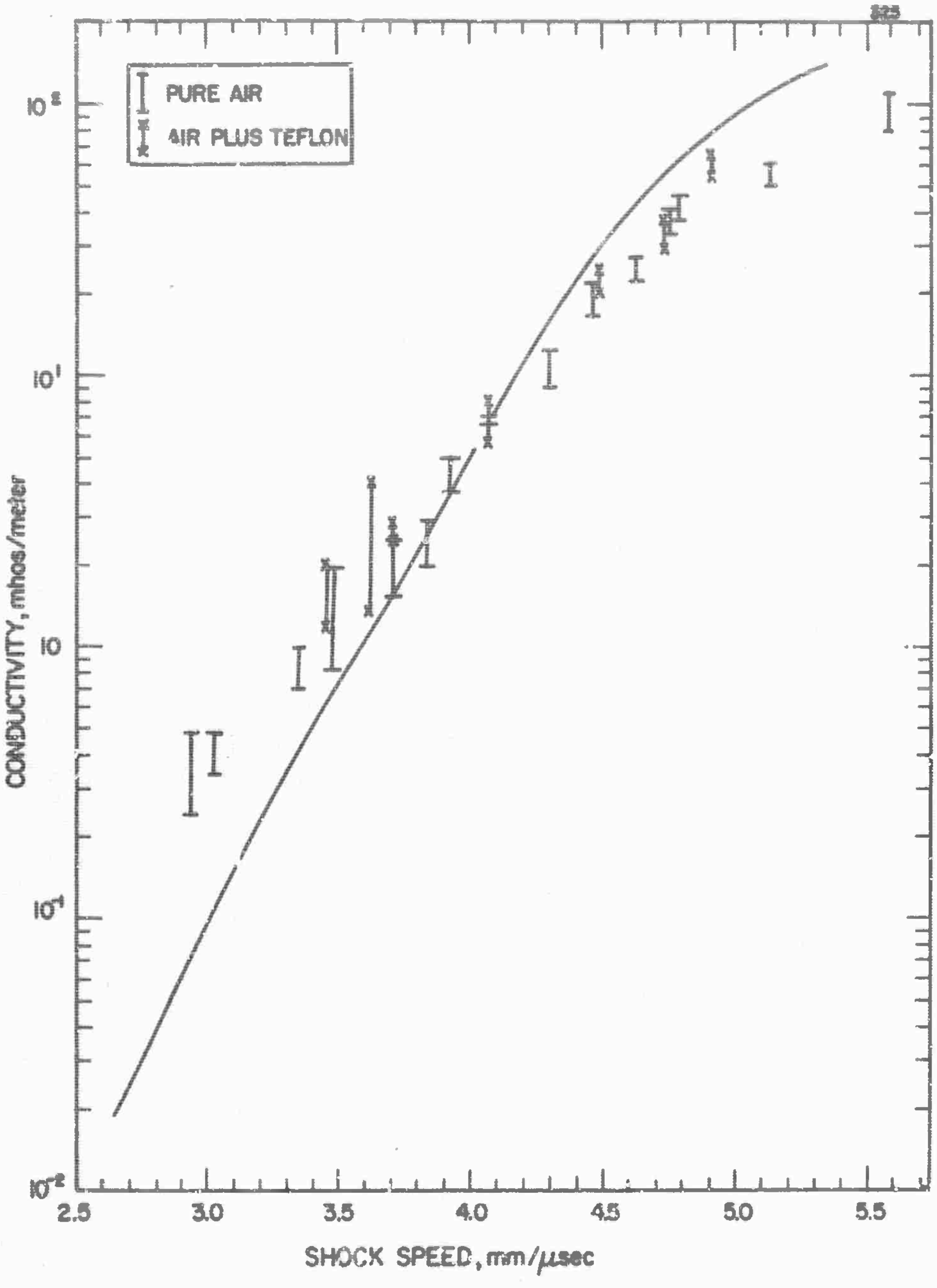

Fig. 10 Conductivity of shock-heated air and air-plus-teflon mixtures for an initial shock-tube pressure of 1 cm Hg. The solid line is a theoretical curve for pure air in equilibrium.

of the air-plus-teflon mixture are probably not quite the same as the properties of pure air will not introduce much error here, since ρ_1 / ρ is only about 10%.

All the data shown on Figs. [illegible], 9, and 10 were taken using the Heliodyne 3-inch diameter shock tube with a combustion driver. In all cases the initial pressure of the air or air-plus powder mixture was 1 cm Hg. The driver was loaded with a mixture of 1 part oxygen, 2 parts hydrogen, and 7 parts helium at total pressures ranging from 60 psi to 1500 psi.

In order to obtain as uniform a powder distribution as possible without injecting too much powder, the injector tank was filled with air to 5.4 cm Hg, the mylar diaphragm at the dump tank entrance was omitted, and the air-powder mixture was injected into both the shock tube and the dump tank, with a final pressure of 1 cm Hg. This process is described in detail in Heliodyne Corporation Research Note 24[5]. By means of a computational procedure developed by W. J. Hooker[5, 6] the concentration of Teflon in the air has been determined to be about 1 mole percent.

3.3 CALCULATION OF THE THEORETICAL CURVE

The solid line of Fig. 10 is a theoretical curve for pure air computed in the manner suggested by Lamb and Lin[2]. The conductivity of the ionized gas mixture is given approximately by

$$\sigma = \frac{n_e e^2 \bar{\tau}}{m_e} , \tag{14}$$

where n_e is the number density of free electrons, e is the electron charge, m_e is the electron mass, and

$$\bar{\tau} = \frac{1}{\bar{C} \sum_j n_j \bar{Q}_j} \tag{15}$$

is the mean free time of electrons in the gas mixture. The quantity $\bar{C} = 2\sqrt{2kT/\pi M_e}$ is the mean speed of the free electrons, n_j is the number density of the j-th gas species, and $\bar{Q}_j$ is the averaged electron diffusion cross section (or momentum transfer cross section) of the j-th gas species. Values for n_j are obtained from equilibrium composition tables[4] and are plotted in Fig. 11 as a function of temperature. Values for n_e are also obtained from these tables. The temperature T and density ρ behind the shock are needed to interpret the composition tables and are obta ed for various shock speeds and a given initial shock tube pressure n normal shock property tables[4]. Values for T and ρ/ρ_0, where ρ_0 is 1.29 × 10^{-3} g/cm^3, are plotted against shock speed in Fig. 12. The cross sections Q_j depend on temperature only and are obtained from tables given in the paper of Lamb and Lin[2].

For computational convenience Eqs. 14 and 15 may be reduced to the following form:

$$\sigma = \frac{0.452 \times 10^{-11} \, n_e}{\sqrt{T} \sum_j n_j \bar{Q}_j}, \tag{16}$$

where n_e and n_j are in the same units, T is in $^\circ$K, $\bar{Q}_j$ is in m^2, and σ is in mhos/m. In Fig. 13 a plot of the denominator of Eq. (16) is compared with n_e to demonstrate how rapidly n_e varies in comparison with the other factors governing the value of σ.

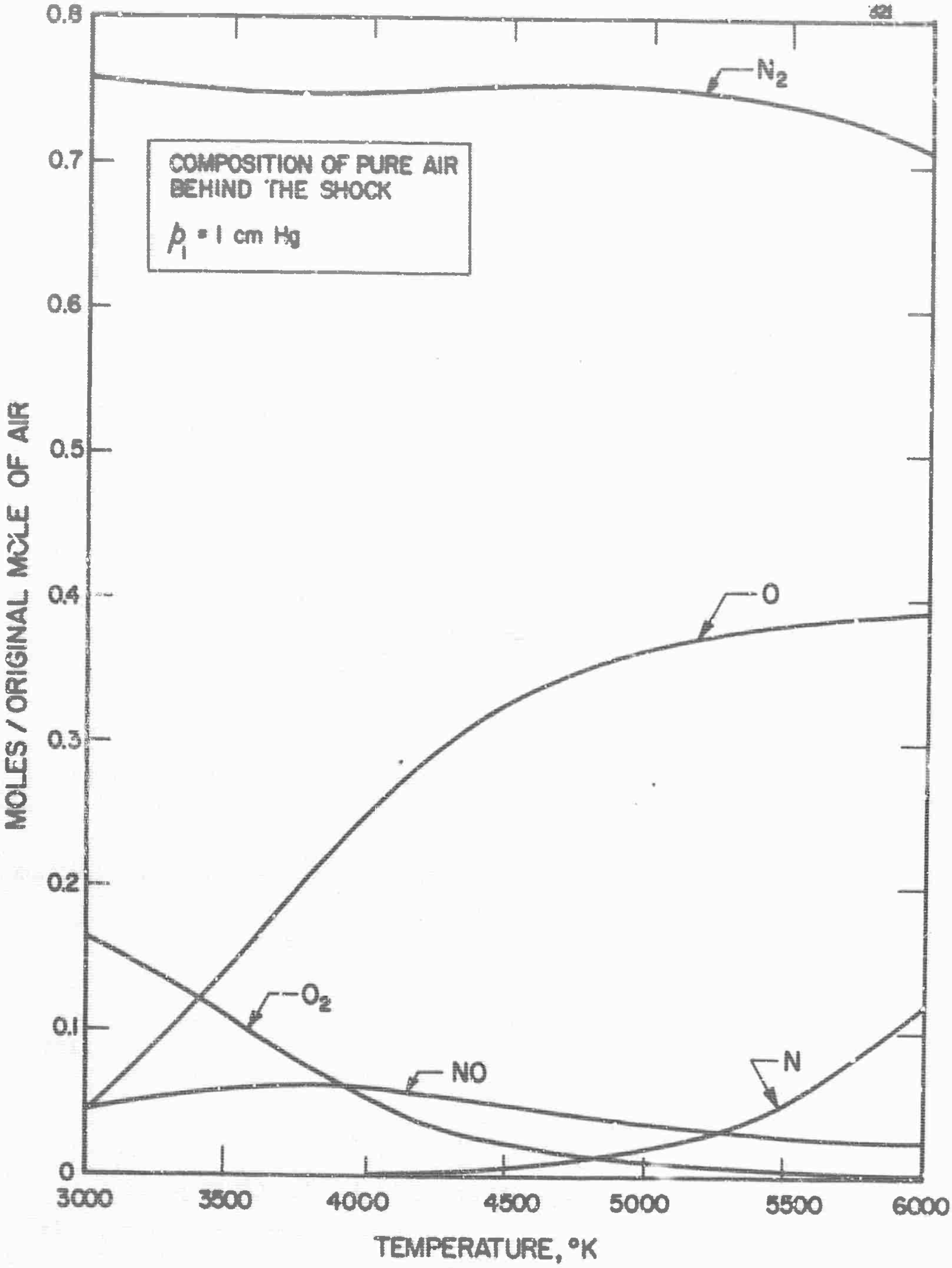

Fig. 11 Equilibrium composition of pure, shock-heated air for an initial pressure of 1 cm Hg.

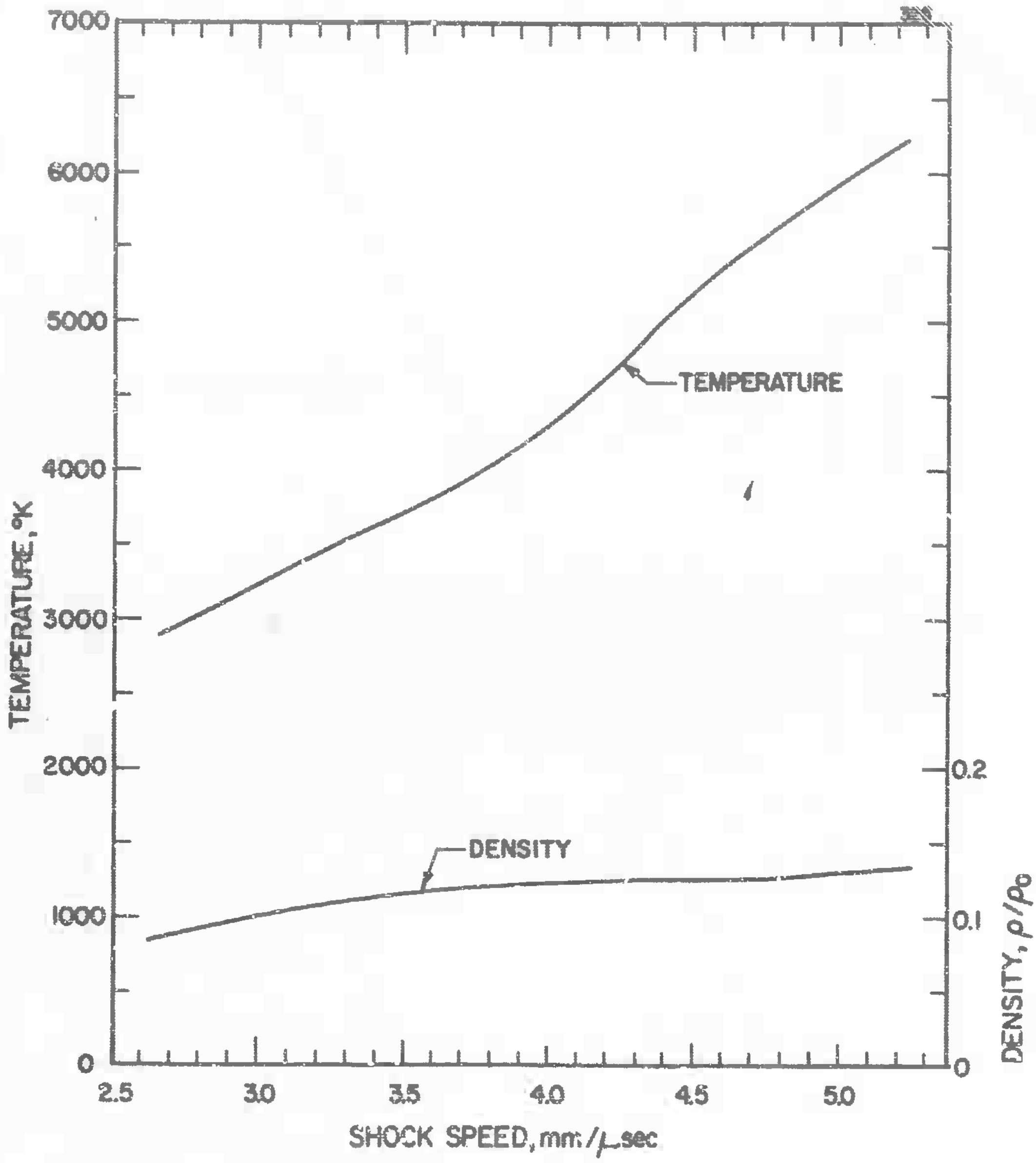

Fig. 12 Equilibrium temperature and density versus shock speed for pure air for an initial pressure of 1 cm Hg.

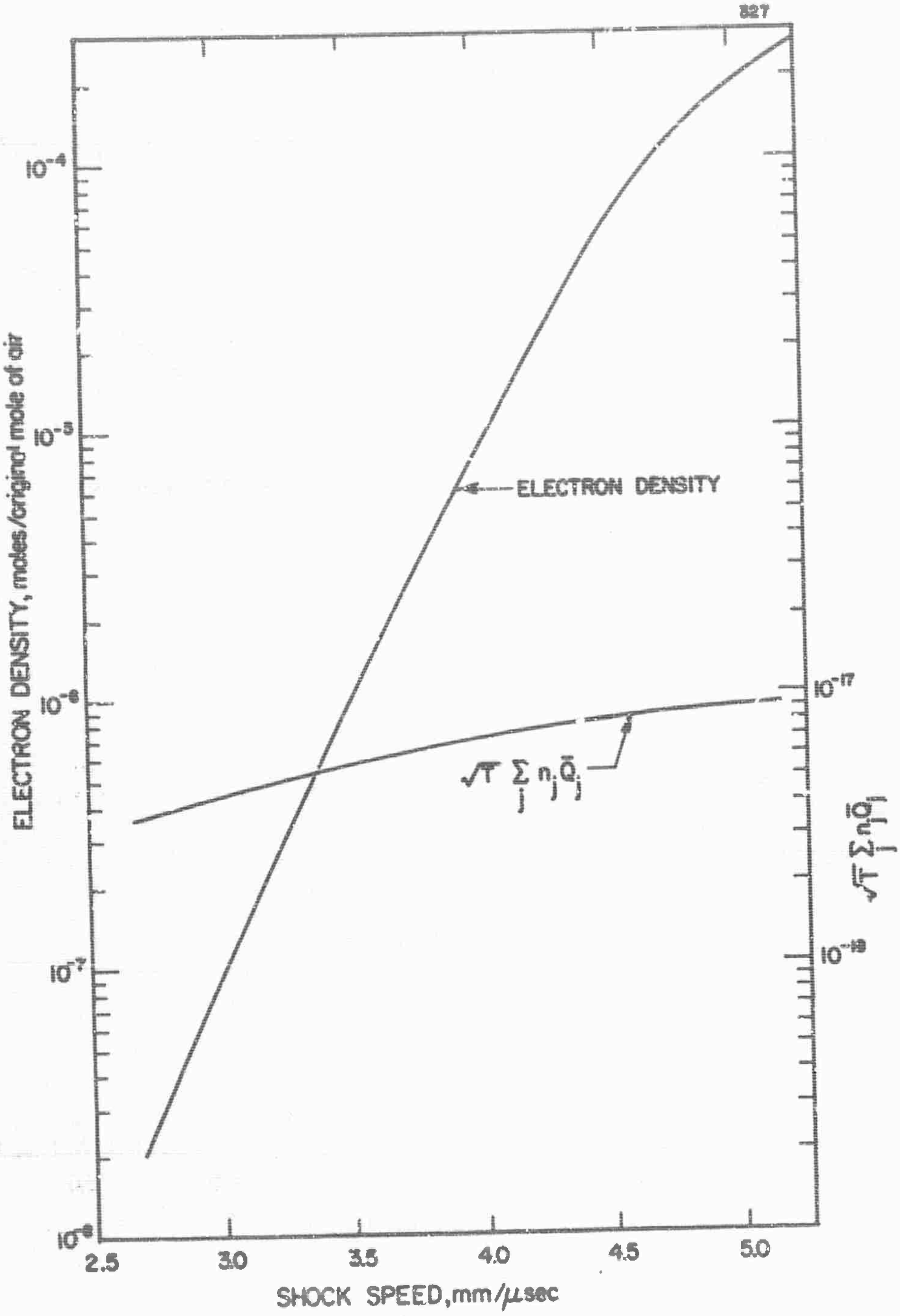

Fig. 13 Comparison between the electron density and $\sqrt{T}\sum_j n_j\bar{Q}_j$ versus shock speed for 1 cm Hg initial pressure.

4. CONCLUSION

For small quantities of material added to the shock-tube test gas, the method described above for measuring conductivity certainly may be applied to the determination of electron density, since the small amount of added powder would be expected to have rather little effect on the temperature or the electron collision frequency in the shock-heated gas. Then a percentage change in conductivity as the result of adding powder would be ascribed to an equal change in electron density. Higher concentrations of powder will alter the temperature and electron collision frequency, but even then changes in conductivity of more than a factor of perhaps 2 will correspond to similar changes in electron density, since temperature and collision frequency are such slowly varying functions of the other variables. Measurement of the temperature and pressure behind the shock, in conjunction with the conductivity measurement, will soon be possible and will greatly improve the accuracy of determination of electron density. Then the values for some of the electron collision cross sections will be the only uncertain factors.

It is evident from Fig. 10 that a small amount of teflon has very little, if any, effect on the conductivity of shock-heated air. Examination of Figs. 8 and 9 reveals no systematic differences between the shapes of the conductivity profiles for the pure air and the air containing teflon. The resolution of the device is good enough (2.4 cm) so that variations in height along the plateau of the signal represent actual variations in conductivity along the column of hot gas. For the slow shock speeds it is apparent from the shape of the conductivity profiles that ionization equilibrium is not achieved during the test time. Calculations will be performed to determine whether these slow ionization rates agree with the theory. Reasons for the wiggles in the plateaus of the conductivity profiles

for the higher shock speeds are not well understood and require further investigation.

REFERENCES

1. Lin, S. C., Resler, E. L., and Kantrowitz, A., J. Appl. Phys. 26, 95 (1955).

2. Lamb, L., and Lin, S. C., J. Appl. Phys. 28, 754 (1957).

3. Lin, S. C., Neal, R. A., and Fyfe, W. I., Phys. Fluids 5, 1633 (1962).

4. Hochstim, A. R., Equilibrium Compositions, Thermodynamic and Normal Shock Properties of Air with Additives, Vol. 1, General Dynamics/Convair, December (1961).

5. Holden, R. R., and Hooker, W. J., "The Preparation and Injection of Teflon/Gas Dispersions for Shock Tube Investigations," Heliodyne Corporation Research Note 24, June (1965).

6. Hooker, W. J., and Morsell, A. L., "Burnup Rates of Powders Behind a Normal Shock Wave," Heliodyne Corporation Research Note 25, June (1965).

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.
No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.
No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.
No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.
No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3. No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3. No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.
No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

Heliodyne Corporation, Los Angeles, California 90064
ELECTRICAL CONDUCTIVITY OF SHOCK-HEATED AIR AND AIR PLUS TEFLON MIXTURES, by A. L. Morsell. June 1965. 31 p. incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 20) (Contract No. DA 04-495 AMC-458(Z))

Unclassified Report

The electrical conductivities of shock-heated air and air-plus-teflon mixtures have been measured using a method similar to the conducting gas-magnetic field interaction method described by Lin, Resler, and Kantrowitz.[1] All measurements were made for an initial shock-tube pressure of 1 cm Hg. The air-teflon mixture contained about 1 mole percent of teflon. The shock speeds ranged from 2.93 to 5.58 mm/μsec corresponding to temperatures between 3150°K to 6500°K and conductivities between 0.24 and 111 mhos/m. The electron densities corresponding to these conductivity values range from less than 10^{11} electrons/cm^3 to about 10^{15} electrons/cm^3.
No difference in conductivity between the air and air-teflon mixtures was observed. Except for two conductivity values measured for very low shock speeds, all the measured values differ by less than a factor of two from theoretical values computed for pure air in equilibrium.

UNCLASSIFIED

1. Electrical conductivity
2. Ablation products
3. Shock tube
I. Title
II. Morsell, A. L.
III. Heliodyne Corporation Research Note 20
IV. Contract No. DA 04-495-AMC-458(Z)

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED